Lyotrophic Phases of DNA

Melani Potrč[1,2,3], **Irena Drevenšek Olenik**[2,4] **and Lea Spindler** [5,2]

[1] University of Maribor, Faculty of Natural Sciences and Mathematics, Maribor, Slovenia; email: melani.potrc@student.um.si
[2] Jožef Stefan Institute, Department of Complex Matter, Ljubljana, Slovenia
[3] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
[4] University of Ljubljana, Faculty of Mathematics and Physics, Ljubljana, Slovenia
[5] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia

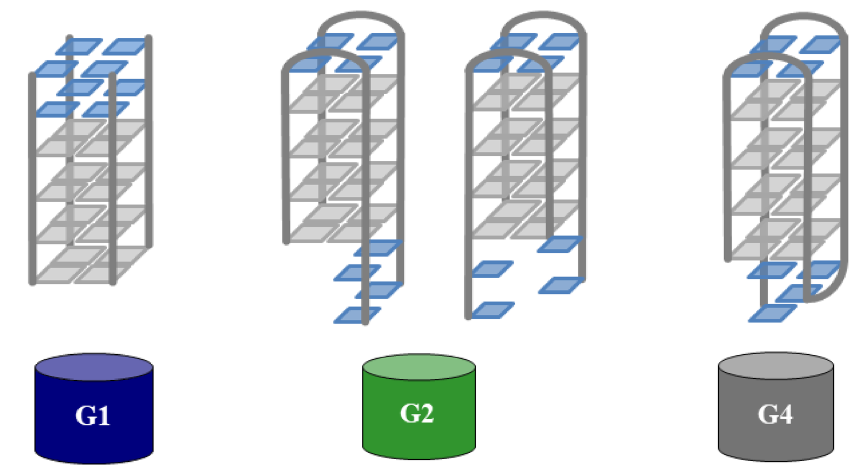
University of Maribor

Jožef Stefan Institute

The 4th Polish-Slovenian International Seminar on Young4SoftMatter DAY
2nd February 2026

Soft Matter

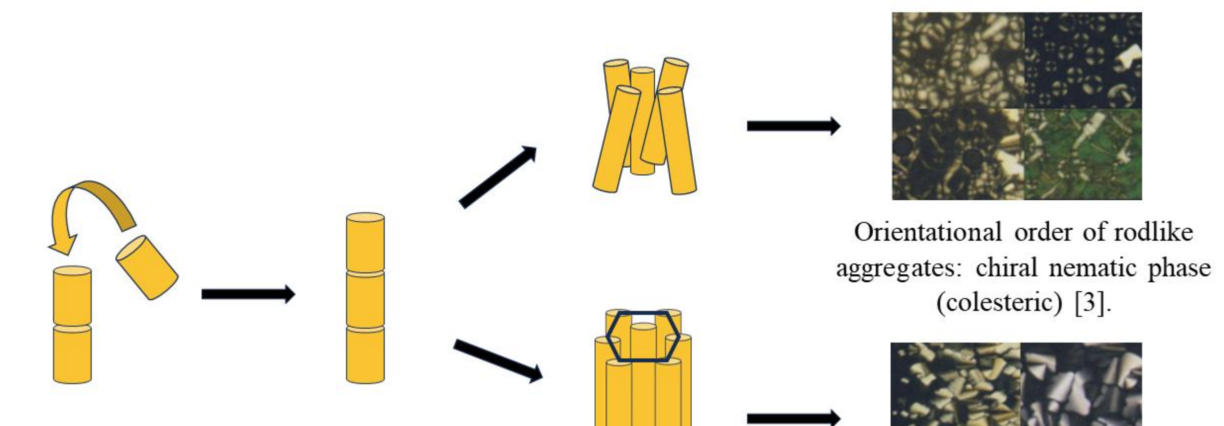
Introduction to $d(G_4C_2)_n$



- We studied quadruplex formation of sequences $d(G_4C_2)_n$ with n = 1, 2 and 4 in concentrated aqueous solutions.
- The $d(G_4C_2)$ sequence forms a tetrameric symmetric quadruplex with 3'-CC overhangs.
- The $d(G_4C_2)_2$ sequence shows a high **polymorphism** with the most possible form of two stacked dimeric quadruplexes.
- The $d(G_4C_2)_4$ sequence forms an unimolecular antiparallel quadruplex with edgewise loops.
- Increased numbers of these $\mathbf{d(G_4C_2)}$ repeats within the ***C9orf72* gene** were identified as the most common mutation associated with neurological disorders, **amyotrophic lateral sclerosis (ALS),** and **frontotemporal dementia (FTD)**. While the normal repeats include up to 25 copies, it can expand to several thousand in patients with the mutation [1].

Liqud Crystals in DNA solutions

- previous research

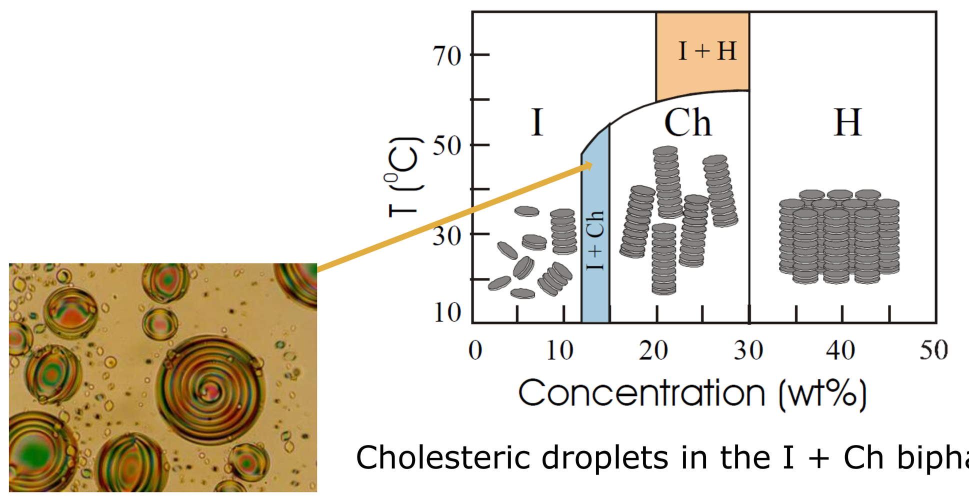


Stacking of DNA sequences into long rods.

Orientational order of rodlike aggregates: chiral nematic phase (colesteric) [3].

Orientational order at higher concentration: columnar phase [3].

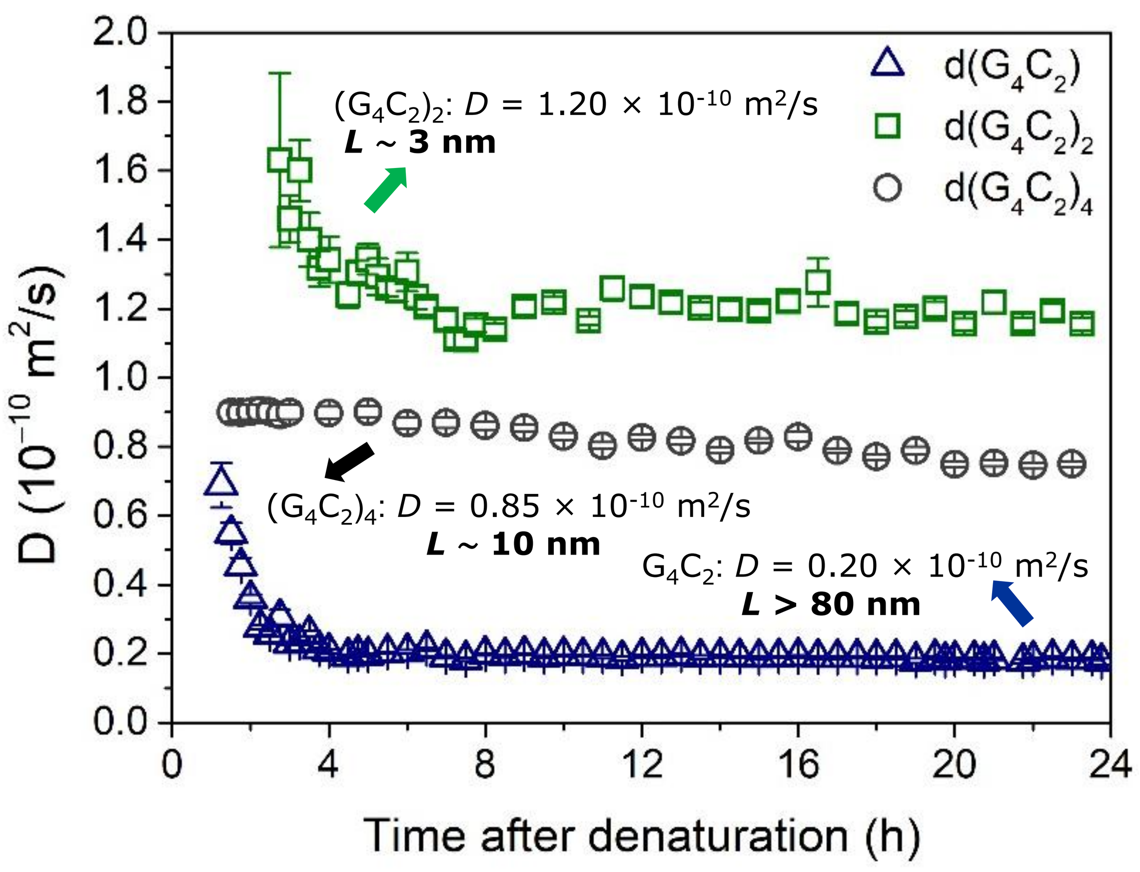
Liqud Crystalline Phases of Guanosine quadruplexes - previous research

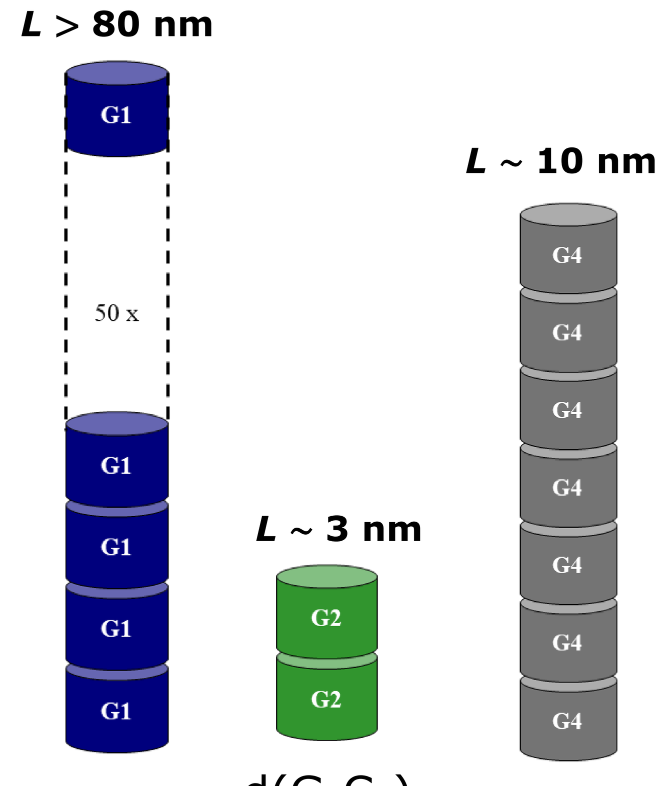


Phase diagram of guanosine molecules ($dGMP/NH_4$) in aqueous solutions [4].

Cholesteric droplets in the I + Ch biphasic region [4].

Results



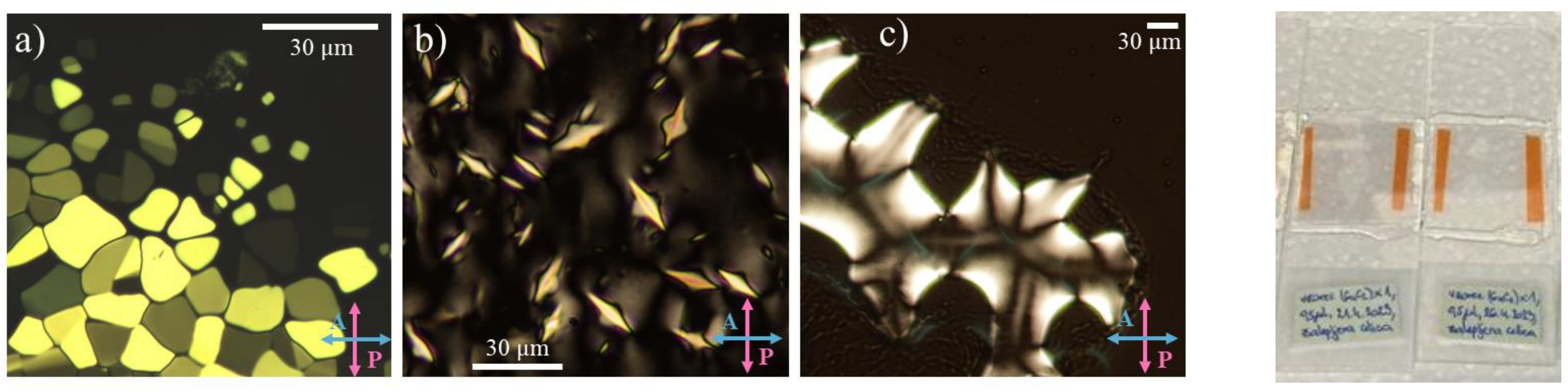


By dynamic light scattering we determined that $\mathbf{d(G_4C_2)}$ formed **extremely long stacks** of quadruplexes with **lengths beyond 80 nm**. The $\mathbf{d(G_4C_2)_2}$ formed a relatively **short stacked dimeric quadruplex**, while $\mathbf{d(G_4C_2)_4}$ formed **multimers** corresponding to **seven stacked intramolecular quadruplexes** [2].

Liquid Crystalline Phases of $d(G_4C_2)_n$

We prepared **highly concentrated** (c > 50 mM) aqueous solutions of G_4C_2, $(G_4C_2)_2$ and $(G_4C_2)_4$.

After a short evaporation period, the solutions were incorporated into thin glass cells and imaged by **polarization optical microscopy** (POM).



- We found that all three sequences showed extensive orientational ordering of quadruplex aggregates and the formation of liquid crystalline (LC) phases.
- The sequence $d(G_4C_2)$ forms columnar LC phases similar to those formed by long DNA molecules at high concentrations [3]. The shorter stacks of $d(G_4C_2)_2$ and $d(G_4C_2)_4$ forming columnar LC phases, however, were surprising.

References

[1] DeJesus-Hernandez, M.; et al.; *Neuron* **2011**, 72, 245-256.
[2] Potrč, M. et al.; *Int. J. Mol. Sci*. **2021**, 22, 4532
[3] Nakata, M. et al.; *Science* **2007**, 318, 1276-1279.
[4] Spindler, L. Self-assembly of deoxyguanosine 5'-monophosphate in aquenous solutions: dissertation (Fakulteta za matematiko in fiziko, Ljubljana, 2001).

Acknowledgement

This work was supported by Slovenian Research Agency in the framework of the research programs P1-0192 and P1-0403.

Methods

Dynamic Light Scattering (DLS)

We determined the **diffusion coefficient** of aggregates from DNA-sequences $d(G_4C_2)_n$. The measurements were made with a Digital Correlator with an avalanche diode as a detector. The source was a frequency-doubled Nd:YAG laser with a wavelength of 532 nm. Scattered light was collected for scattering angles between 30° and 140°.

Intensity autocorrelation function:

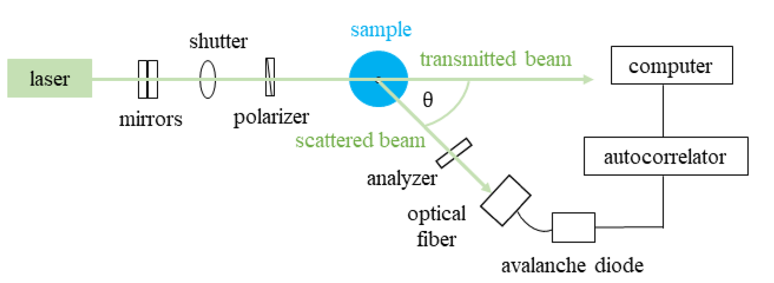
$$g_2 = \frac{< I_s(q,0) I_s(q,t) >}{< I_s(q,t) >^2}$$

→ Calculation of the **diffusion coefficient**:

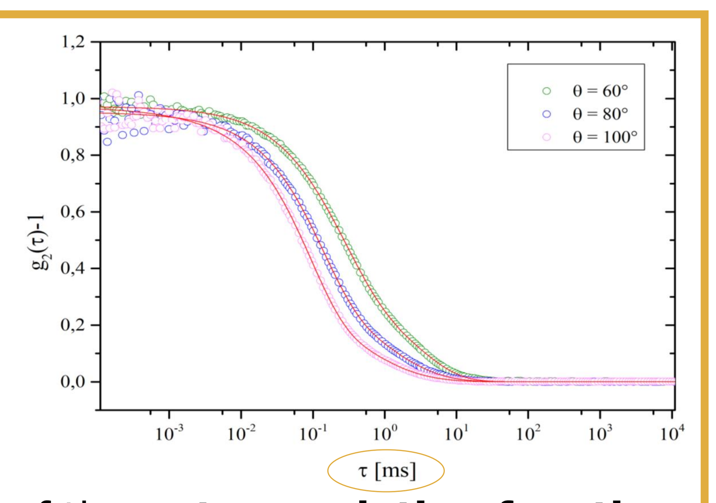
$$D = \frac{1}{\tau q^2}$$

→ For noninteracting cylindrical rods their **length** is related to D as:

$$D = \frac{k_B T\,(\ln p + v)}{3\pi\eta L}$$



We calculated the **aggregate length** from the diffusion coefficients.



The equation of the **autocorrelation function**:

$$y = y_0 + \left[1 + j \cdot \left(a_1 \cdot e^{-(\tau \cdot f_1)^{s1}} + (1 - a_1) \cdot e^{-(\tau \cdot f_2)^{s2}} - 1\right)\right]^2$$